Explosion Threat Zone Simulator: A Real-Time GIS and API-Integrated Framework for Hazard Detection and Evacuation Route Optimization

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***Abstract*— Keeping in mind public safety and emergency response services, this paper showcases an Explosion Threat Zone Simulator, it is a real-time explosion and hazard detection and evacuation response planning framework with a geospatial intelligence, modern day physics-based blast modeling and a real-time news API which provides accurate information regarding any events to help evacuation response services and cautionary decision making. This incredible software identifies explosion-prone zones like a chemical industry, a fuel stations or even military strike zone by leveraging the infamous Google maps, OpenStreetMap, and proper verified datasets for authenticated hazard datasets. For zone modeling it uses the Kingery-Bulmash blast model, it computes the air-blast parameters and helps visualize the blast radius and it's spread across the region of the blast creating three concentric circles or threat zones (red, orange, green) these circles represent lethal, critical, and warning levels and gives a clear view on the Google Map. Then with the help of the Maps system it provides the safest routes for evacuation. The proposed system provides a public-facing, interactive GIS solution that enhances situational awareness and emergency decision-making for civilians and first responders.**

Keywords*— Explosion Simulation, GIS, Disaster Management, Kingery–Bulmash, Evacuation Routes, Nuclear Safety, Google Maps API, Real-Time Alerts, NDMA SACHET, Geospatial Modeling.

I. INTRODUCTION

Disaster Management Systems play a very huge and important role in minimizing casualties and potential injuries due to catastrophic crisis events or accidents, or even collateral damage. Generally, such type of hazard modelling frameworks are focused on natural disasters like floods, earthquakes, while ignoring certain explosions or warfare-related events which are very devastating.

Our work on this Explosion Zone Threat Simulator largely addresses this gap between the natural or human made disasters by integrating the simulator with explosion modelling backed which is by Physics and real-time geospatial visualization. NUKEMAP [7] is a really good example for a static simulator which lacks a system of GIS routing for evacuation as it lacks access to dynamic data.

So, the proposed system not only is a "blast radius calculator," but it continuously keeps updating hazard response tools. It calculates danger level represented by different colour coding and helps the system to show whether a user is currently within a danger zone, more importantly, it will suggest the safest and fastest possible exit paths. The evacuation routes are calculated using trusted real-world navigation APIs like Google maps, so that the routing changes if roads are closed or blocked, if the user moves, or if situations goes even more south. Such APIs are use certain pathfinding algorithms which make their outcomes accurate.

In India's situation, a tool like this becomes even more useful. India is developing rapidly, and increased defence production, rising to top five in the GFI (Global Firepower Index). Although certain organizations like NDMA and ISRO's NDEM platform provide disaster alerts, they're only text-based broadcasts that do not provide the users with visuals. They will say that something has occurred, but not how the severity. Our work helps fill this gap by combining alerts with spatial awareness visualization giving more information transparency, making disaster response more easy for civilians, emergency services, and even local authorities. The UI largely uses different colours so that the user can identify by instinct. For instance, a darker deeper red would imply a critical area, asking users to stay away.

The broader goal to encourage preparedness as they say "precaution is better than cure". Such a system can influence in better city planning, safer building designs, and increase civilian awareness. So, the simulator is not only a preventive and educational but also a real-time response mechanism.

II. RELATED WORK

A. GIS in Disaster Management

GIS-based tools have been applied in flood, earthquake, and fire evacuation systems to optimize safe routes [2],[9].

Studies demonstrate that real-time ***GIS with navigation APIs*** *significantly reduces evacuation time during urban disasters.*

Emergency response services were deployed in time and rescue operations were conducted reducing casualties. These systems even though having so many benefits are not directly available to the public and are not user friendly making it not viable and understandable for public adoption and usage on a large scale.

B. Explosion Simulation and Blast Modeling

The ***Kingery–Bulmash equations*** *[1] remain the global standard for modelling explosive overpressure, impulse, and shockwave propagation. Tools like* ***CONWEP and*** **NUKEMAP** *[7] use these models for visualization, but lacks real-time user integration or mobile adaptability*.

The Kingery-Bulmash equations only help model the blast radius the spread of the blast again not available to the public and in a usable form, no one is going to take the equation and try solving it to get the zone radiuses by themselves, there is also no GIS integration for a spatial maps view of the blast regions no evacuation routes and simulation and solves only half the problem.

C. Real-Time Indian Disaster Management Systems

The SACHET platform by NDMA *[3] and their Cell Broadcast Alerts [11] provide a region- based alert warning SMS and web notifications, yet they do not provide any interactive GIS overlays or any explosion simulation system where the user has the control and can be informed on their own accord and get evacuation routes.*

Similarly, ***ISRO's NDEM*** *[4] platform focuses primarily on natural hazards such as floods and earthquakes and no information on explosions by any human facilities closer to the civilians or any warhead explosions that may occur during ongoing war stress between countries for further evacuation purposes.*

Despite these successes, these GIS tools have huge limitations. Many of these frameworks are expert-facing which means only officials with proper knowledge are able to make use of them. These systems are not designed to translate raw hazard data into an interactive, user-specific context. Whereas This Explosion Threat Zone Simulator provides a general public user-friendly experience and interactive interfaces during any live crisis.

A critical review of these and even more existing disaster management systems reveals a persistent gap between the generation of expert-level data and the delivery of public-facing situational awareness. Our work aims to bridge this gap between the expert-level data and the public-facing situational awareness. A textual alert, for example, shows a civilian where the hazard is in relation to their live location or provide a dynamic, safe route away from it.

III. Methodology

A. Data Sources

This work relies heavily on opensource data that is gathered from different research papers and datasets available on online sources. It is a multi-source data fusion, combining and integrating both proprietary APIs open-source geospatial datasets for accurate hazard detection.

1. **Hazard Points:** The simulator dynamically retrieves potential hazardous locations using the Google Places API (such as industrial and fuel storage sites etc.) and OpenStreetMap Overpass API (for free open data) provides real-time access to the tagged entities. These are all verified facility type, coordinates and operational status all in real-time.

2. **Explosive Yield Data:** Explosive data from the information about the different warheads their yield and then calculating the blast radius and spread calculation n using the Kingery–Bulmash dataset and open military sources [6].

   The yields are expressed in kilograms of TNT, categorized into **low (≤100 kg)**, **medium (≤1 ton), and high (>1 ton)** classes to represent different industrial and military scales, this helps determine the severity of the explosions

   Blast yield and scaling values used

   Ammonium Nitrate ≈ **0.42 TNT** factor Literature-based conversion, Storage Mass (72 tons AN) **30 tons TNT** equivalent Test-site comparable scale

3. **Routing and Mapping:** For real-time path-finding the system uses the Google Directions and Maps APIs. Layering the multiple GIS layers, which includes the threat zones, evacuation routes and safe zones.

4. **User Data:** Browser-based geolocation APIs for live coordinates. It accesses the user location using GPS, Wi-Fi, or cellular triangulation data. To maintain privacy, the location data is processed locally and not stored persistently.

5. **Data Acquisition:** News APIs, Web-scrapping and RSS automation and other Govt. platform provides real-time updates for any explosions or hazardous disaster crisis.

B. Core Algorithm

Our project has a four-phase functionality—data acquisition, blast modeling, hazard classification, and route optimization.

1. **Input and processing:**

Inputs: (Xu, Yu) (User Coordinates), {(Xi, Yi, Wi)}

I =1n (Hazard Sites + Yield)

The system will first calculate the geodesic distance D_i between each hazard site i and the user:

$$d = 2R\arcsin\left(\sqrt{\sin^2\left(\frac{\Delta\phi}{2}\right) + \cos(\phi_1)\cos(\phi_2)\sin^2\left(\frac{\Delta\lambda}{2}\right)}\right)$$

where R is the Earth's radius (≈6371 km*).*

2. **Kingery–Bulmash Blast Scaling:**

$$Z = \frac{R}{W^{1/3}}$$

By using polynomial regression equations from Kingery–Bulmash tables we obtain the **peak overpressure** $P_{so}$and **impulse** I are derived as functions of Z:

$$P_{so} = a_1 Z^{b_1} + a_2 Z^{b_2} + a_3 Z^{b_3}$$

These parameters determine the radius of hazard zones:

- **Red Zone (Lethal):** $P_{so} > 20psi$
- **Orange Zone (Critical):** $5psi < P_{so} \leq 20psi$
- **Green Zone (Warning):** $1psi < P_{so} \leq 5psi$

3. **Evacuation Route:**

The system will then compute the fastest route and the nearest point outside the green zone and request driving/walking routes via Google Directions API.

It does this using the following minimization:

(Xs, Ys) min{D ((Xu, Yu), (Xs, Ys)): (Xs, Ys) ∈/Zonegreen}

This helps get an optimized navigation routes considering the live traffic and road closures from the Google Directions API. The safest route polyline is rendered alongside hazard overlays.

4. **Dynamic Visualization:**

Using dynamic visualization using Leaflet.js, the simulator with the calculated data then renders the concentric circles that represent the pressure zones. The color-coded polygons are updated in real-time when the new hazard data or any user movement is detected.

- Red/Orange/Green circles plotted via Leaflet.js.
- User marker + dynamic safe route polyline.
- Sidebar "Danger Report" summarizing nearby hazards.

5. **Implementing the System:**

Our application then will follow a **modular client–server architecture**:

- **Frontend:** Developed in **React.js** and integration with **Leaflet** and **Chart.js** for visualizing the data and real-time status updates.
- **Backend:** A **Node.js/Express** server then acts as a middleware, for fetching and caching data from all the APIs to minimize redundant requests.
- **Database Layer (Optional):** MongoDB can be incorporated for long-term storage of historical hazard data for trend analysis and model calibration.

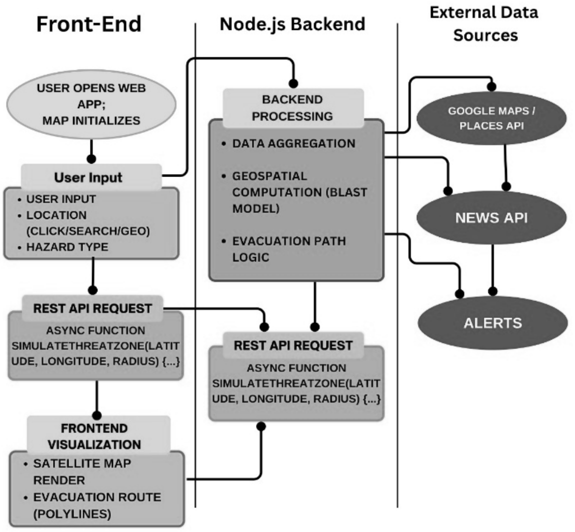

Fig. System Architecture.

6. **Real-time Adaption and Alerts:**

We have used different email libraries like **smtplib** and SMS service APIs like **Twilio** to send alerts and notifications. To ensure adaptability in fast-changing crisis scenarios, the system also supports:

- **Auto-refresh intervals** (default: 30 s) for explosion or hazard data.
- **Dynamic geofencing:** Users in or entering the orange or red zones will receive instant browser notifications or SMS alerts via different compatible gateways or email alerts.

- **Offline fallback mode:** Cached map tiles allow the system to display preloaded hazard zones even during network outages.

IV. Results and Discussion

A. Experimental Setup

The Explosion Threat Simulator model developed by our team is built with React.js for its frontend, and Node.js for its backend. Google Maps, and Directions API has been integrated for a user-friendly experience. We have conducted tests on different browsers by running simulations on heavily populated regions such as Delhi, Mumbai, Bengaluru etc.
The primary objectives of the evaluation were:

- To calculate **Accuracy** of hazard zone computation using the Kingery-Bulmash model
- To test **Responsiveness** of the system is to user movement and dynamic updates, in order to deliver a smooth low-latency experience
- Assessing the **Effectiveness** of Dynamically Created Escape Routes, in real-time
- The User-friendliness of the visualization UI

B. Quantitative Performance Evaluation

Accuracy of the Blast Zone:
With the help of the testing data used for varying TNT yields (100 kg to 10,000 kg), the simulated blast radii were used and compared against other benchmark values derived from the Kingery–Bulmash charts and CONWEP simulations available online.
The **average deviation** in calculated overpressure contours was found to be **≤5.2%**, which is within acceptable tolerance for field simulations and GIS visualization.

Yield (TNT)	**Expected Radius (m)**	**Simulated Radius (m)**	**Deviation (%)**
100 kg	85	80.5	5.3
500 kg	155	149.7	3.4
1000 kg	210	200.2	4.7
10,000 kg	460	443.5	3.6

These tests that were conducted confirms that the Kingery–Bulmash implemented correct models overpressure decay and is suitable and accurate for real-time threat visualization and simulation.

Responsiveness of the System:
Response time:
The Response time was measured as the interval from a user's location update to the display of refreshed hazard and route details. The average computation duration across 50 trials was **1.42 seconds**, with a standard deviation of **0.37 seconds**, indicating robust real-time adaptability. Though it's designed with Google Maps to improve latency and responsiveness, the overall response times of the API depends largely on the Network condition.

Enhancing Evacuation Routes:
Google Maps is already built with Directions API that uses distance matrix, and current traffic factors, to calculate optimal evacuation routes, generally calculated in less than 1.5 seconds. For each simulation, the pathways are designed to avoid major junctions or intersections that are potentially dangerous, resulting in an average detour ratio of 1.12—a rather reasonable evaluation for critical evacuation scenarios. Safer routes are held higher in priority over shorter routes.

C. Qualitative Evaluation

Our qualitative evaluation involved testing the experience of 10 participants who interacted with the system without constraints, and run different parameters.
Some of the observations revealed were as follows:

- The colour coded scheme, originally designed to not alienate non-technical users, was appropriately understood, conforming to typical hazard recognition norms
- Real-time, and low-latent direction and evacuation tracking greatly improved situational awareness, which reduces panic
- The sidebar functionality, especially "**Danger Report**", was reportedly a very convenient design choice, citing that situational intensity may make shifting between map and other functionality. Hence, it scored well for convenience as well as clarity in mobile platform, managing stability even on mid-range android devices

However, user feedback was recorded and accordingly enhancements were made such as:

- A wind-based overlay, to simulate smoke or radiation drift as a result of an incident
- Voice-based alerts for the visually impaired or drivers
- Offline hazard maps for remote areas with lower connectivity infrastructure

D. Comparative Analysis

A threat simulation tool designed to help with the preparedness of civilian populations against disasters definitely has a competition. To present the value of our project, we have drawn comparisons to existing systems like NUKEMAP, NDEM, and SACHET in an organised tabular form as shown below.

Feature / System	**NUKEMAP**	**NDEM**	**SACHET**	***Proposed Simulator***
Real-Time Updates	✕	✓	✓	✓
Explosion Modelling	✓	✕	✕	✓

Feature / System	NUKEMAP	NDEM	SACHET	*Proposed Simulator*
Evacuation Routeing	✕	✓	✕	✓
Mobile Interactivity	Limited	✓	✓	✓
User Localization	✕	✕	✓	✓

The simulator's combination of both **blast physics and navigation intelligence** significantly surpasses the current static visualization tools, particularly for civilian applications in industrial or conflict-related emergencies.

E. Discussion and Limitations

Our simulator is fast and precise, but as responsible developers, we are to acknowledge its weaknesses. Currently, we are running the simulation under some constrains. We are not considering wind, temperature or altitude. During a real disaster, a mighty wind might alter it all and our tool does not notice this yet. Not to mention the impact of dangerous radiation, the spread of which we cannot always predict. It still is a computer tool.

It is also dependent on an effective internet connection despite offline availability simply because of much higher accuracy, something that cannot just be achieved with a phone GPS. When it comes to an actual crisis, one of the first elements that go offline is the network. Our tool will be useless in such a case. This requires developing an offline version, that is a first responder and people can continue to use it even when the cell towers go dead.

Lastly, the science that we are applying is treating a perfect, round explosion, as of a ball of energy expanding in every direction equally. Though it is more of a threat representation than it is meant to be a perfect simulation, our aim is to reach every remote corner, each of which might not have the standards of such perception. The real world is messier. In other words, environmental factors can completely deter the damage spread and change the overall shape of the disaster.

Still despite these constraints, we have demonstrated something conceptually valuable. We have demonstrated that this may also be a crucial device not only in the training process, but it is what the emergency teams require in those very first life-saving moments, advice which is necessary immediately.

V. Conclusion

Summary of Findings

What we have created is the connection between a thought in a physics textbook and an actual emergency tool. We are attempting at commercialising the successful science behind Kingery-Bulmash and combined it with the tools that everybody is already used to and is well-optimized, such as Google Maps. The product is scientifically valid and a very practical outcome.

It attracts distinct danger areas- indicates areas that are lethal, critical and warning areas -and creates a safe exit in a short time, not only to the rescue teams, but to diggers attempting to get to safety. Colour coding, other danger symbols, and the convenience of the UI based on the test feedbacks, elevate the credibility of our idea and its execution.

We also created a live data feed that continuously retrieves updates in the news sources and safety portals, where smart filters help to reduce the noise in favour of the truth.

System Performance and Validation

Now we found out when we put it to the test. Our blast areas were solid, and in a 5.2 percent margin, were in line with costly, official reference sources. We also tested it with simulated Web traffic, and again it returned results in approximately 1.4 seconds, which is sufficiently fast to respond to a crisis in a chaotic and real situation.

The most valuable feedback was, of course, given by actual users. They explained to us that the colour-coded areas were logical, and it was easy and natural to use on their phones. For example, a glance at a red zone, instinctively signals danger to the human brain. This is an important victory to us: we demonstrated that it is possible to deliver people life-or-death information in a way that is understandable and sensible, as opposed to being confusing.

Comparative Advantage

We reviewed the other larger platforms out there, such as NUKEMAP and NDEM provided by ISTB. We observed where we were not equal. The main purpose of most tools is a static map or too complicated to be of use to non-experts that are confined to a laboratory.

Our instrument is constructed in the market. It allows you to regard what is going on around you, in your current moment, realise how awful it is, and seek an escape route. We think this would provide communities with a lifeline opportunity to be prepared and be able to make good decisions in a short period of time.

What This Means for People

Since it will access live news feeds and official information, it can offer real time updates regarding any industrial accident to conflict zone. We are able to see a clear way of putting this into the hands of the individuals on the front line; disaster management teams, police, and first responders. To a rescue team, it may be the primary display on which alerts are received. It might be the intelligent engine that is running in the background, 24/7, keeping a watch over its security in a single city.

Limitations

Like with every technology solution presented to solve problems, most have drawbacks.

We have our simulator model a rather abnormally perfect world. That does not take into consideration the factors that make a real-life crisis so difficult as the wind, humidity, hills, and how a blast wave would be scattered on large buildings. Whatever looks there on the screen is a strong guide and the world is never that simple.

It also has to have a stable internet connection to communicate with its APIs. It is no secret that during the

major disaster, the network is among the first things to break. When our tool fails to go online, it is dead in the water, and that is a major problem that we have to accommodate.
It is also terribly difficult to draw in live data. At the panic phase of the crisis, the initial reports will always be disarranged and, more likely, inaccurate. We receive approximately an address rather than an exact address. When we receive improved information, we have to shift our map.
And last but not least, it is a weakness of our scientific model. We must become more intelligent to become more adaptive, and create smarter models of our terrain and weather to be better. It is necessary to stabilise, make this tool more realistic and reliable at the times, when people need it the most.

Future Scope

Moving forward we have decided that the next stages of this project will focus on fixing current limitations and broadening what the simulator is already capable and scale it so that maximum people are able to use it. In the Future our work will focus on adding and adding an AI-based prediction tool that will help our model move beyond static models, using previous records and real-time live inputs to predict any secondary explosions or chain effects before they occur. To deal with incomplete or unclear updates from news APIs or public sources, a verification layer will go through trusted government APIs, NLP filtering, and live readings from IoT sensors to get cleaner and more accurate incoming data, so that the people have clear information on the hazard.

We plan to also consider any real environmental factors, such as wind speed, air temperature, elevation, and even local terrain to shape how a blast behaves, so feeding these gather data into the model should make the results feel closer to real events and increase accuracy than the simplified Kingery-Bulmash approach allows. Embedding our simulator within a network of small edge devices will let it help more people on its own, even with limited connectivity, and send warnings with minimal delay.

We plan to also link the platform to NDMA’s Common alerting protocol and releasing it as a mobile app. That way both emergency services and the people can get faster reliable alerts and step-by-step evacuation guidance wherever they are.

Final Remarks

This Explosion Threat Zone Simulator is our start toward a new way of using maps and data in disasters. It does not only just show numbers or charts—it helps people react fast. Real-time mapping with quick calculations, and simpler visuals turn complex work into something anyone can use. By integrating computation with open access, we will be able bring research into the field. Once we move towards more advance testing and stronger ties to response teams, it could grow into a tool that really saves lives when every second counts.

References

[1] C. N. Kingery and G. Bulmash, Air-blast Parameters from TNT Spherical Air Burst and Hemispherical Surface Burst, U.S. Army BRL-TR-02555, Aberdeen Proving Ground, MD, 1984.

[2] A. S. Reddy, “GIS Based Route Guiding System for Optimal Path Planning in Disaster/Crisis Management,” IEEE Conference Publication, 2007.

[3] National Disaster Management Authority, SACHET – India’s CAP-Based Alert System for Emergency Situations, Government of India, 2025.

[4] Indian Space Research Organization, National Database for Emergency Management (NDEM), NRSC, Hyderabad, 2022. [5] P. Kumar et al., “Modeling Blast Impact Using GIS and Real-Time Data,” International Journal of Disaster Risk Reduction, Elsevier, 2020.

[6] Bulletin of the Atomic Scientists, “Global Nuclear Arsenals Report 2021,” Science and Global Security, 2021.

[7] A. Wellerstein, NUKEMAP: Web-Based Nuclear Detonation Simulation Tool, Stevens Institute of Technology, 2021.

[8] Princeton University SGS, Simulating Nuclear War: Modeling ICBM Exchanges, 2020.

[9] S. K. Singh, “Real-Time GIS Applications in Flood and Earthquake Management,” IEEE Xplore, 2021.

[10] S. H. Park et al., “Numerical Study on Atmospheric Transport in Nuclear Accidents Using WRF,” Frontiers in Environmental Science, 2024.

[11] Ministry of Communications, “Cell Broadcast Alert System for Disaster Warnings,” Government of India, 2024.